

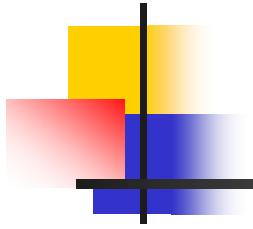
Neutrino-beam Induced Backgrounds and their Determination

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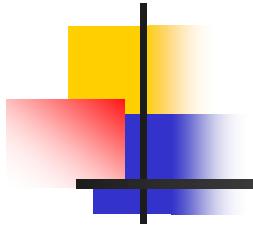


Outline

- Introductory comments/overview (Stan Wojcicki)
- Neutrino cross sections (Tony Mann)
- How to determine beam ν_e backgrounds experimentally (Michal Szleper)

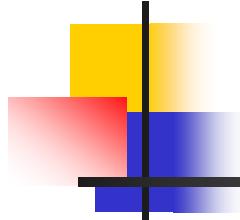
Potential Backgrounds Superbeams

- Beam ν_e 's (from μ and K decays)
 - At some level irreducible (energy resolution important)
- Neutral current (NC) interactions (ν_μ , ν_τ , ν_e)
 - Mainly due to asymmetric decay of $\pi^0 \rightarrow \gamma\gamma$
 - Identification of 2nd gamma (transverse granularity)
 - Origin separated from vertex (longitudinal granularity)
 - Double initial pulse height (pulse height measurement)
- Misidentified ν_μ CC interactions
 - Mechanisms for giving background:
 - Misidentification of μ as electron
 - Missed μ (short) and misidentified (as e) asymmetric π^0
 - Due to oscillations, background lower in FD than in ND
- At low energy ($E_\nu < 4$) $\tau \rightarrow e$ background negligible



General Strategy

- Measure background level in Near Detector(s)
 - Identify relative contribution of different sources
- Extrapolate to get background prediction at the Far Detector

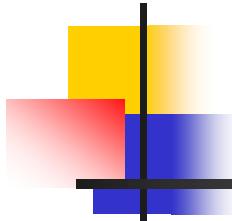


Principal Issues

- How many near detectors are required and of what kind?
- Location of near detector(s)
- How well does one need to know relative contributions from different sources?
- How much information does one need about neutrino reactions?

Relative contributions from different sources (roughly)

- Assume a $\nu_\mu \Rightarrow \nu_e$ signal about 1/10 of the current CHOOZ limit
- Compared to the signal, the backgrounds are:
 - Beam ν_e (~100%)
 - Beam $\bar{\nu}_e$ (~10-15%)
 - Misidentified NC (~30-100% in low Z calorimeter, ~20% in liquid Argon)
 - Misidentified CC (<10% in FD, ~x6-8 larger in ND)
- Backgrounds can be reduced at the expense of decreasing efficiency (for a comparable FOM)
- There is also a tradeoff between size of signal (at smaller transverse distances) and backgrounds



Beam ν_e backgrounds

Ways to measure/calculate them

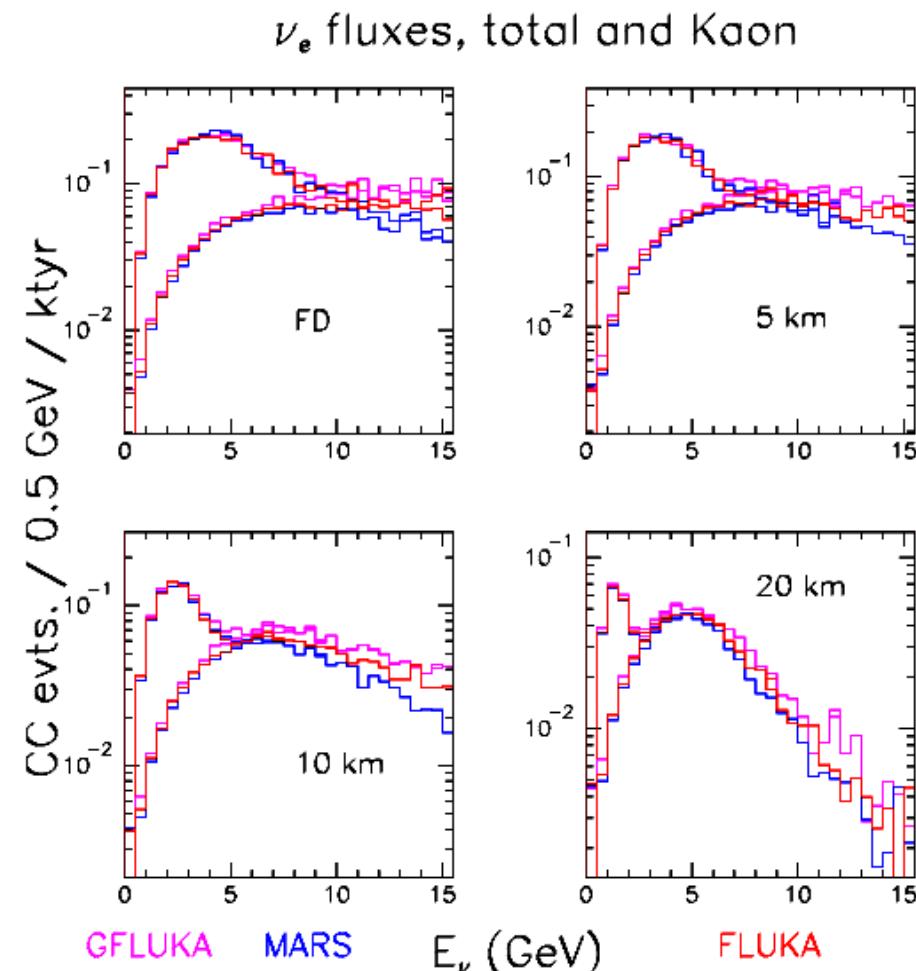
- Prediction from production spectra
 $(\pi \rightarrow \mu \rightarrow \nu_e)$
- Prediction from muon monitor data
(most ν_e 's in relevant energy range come from μ decay)
- Need to rely on MC to obtain identification efficiency

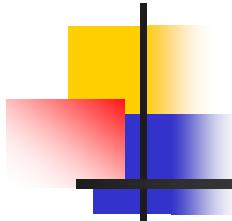
Comparison of predictions for flux of beam ν_e 's

In the 1-3 GeV region
the dominant contribution
is from μ decays

Different production
models predict very
similar yields

(Kopp and Zwaska)





Beam ν_e backgrounds

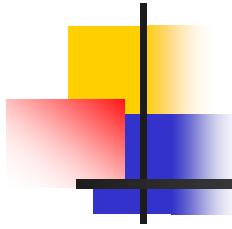
Ways to measure/calculate them

- Prediction from production spectra ($\pi \rightarrow \mu \rightarrow \nu_e$)
- Prediction from muon monitor data (most ν_e 's in relevant energy range come from μ decay)
- Prediction from observations in ND (Szleper's talk)
 - From ν_μ interactions ($\nu_\mu \rightarrow \pi \rightarrow \mu \rightarrow \nu_e$)
 - From $\bar{\nu}_\mu$ interactions ($\bar{\nu}_\mu \rightarrow \mu \rightarrow \nu_e$); how unique is this as a source of $\bar{\nu}_\mu$'s? How well can we estimate contributions from wrong sign π and K^0 decays?
- Changing decay pipe length (complicated and not very sensitive)

Impact of changing length of the decay pipe

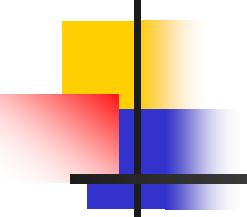
amount filled		MARS			
	0-3 GeV	nu_mu	nu_e	nu_mu/nu_e	S/sqrt(N)
0 m	0-3 GeV	77.09	0.5098	151.2	2145
	All	123.35	1.9582	63.0	1751
100 m	0-3 GeV	76.19	0.4852	157.0	2173
	All	122.10	1.9036	64.1	1758
200 m	0-3 GeV	74.70	0.4563	163.7	2197
	All	120.31	1.8452	65.2	1760
300 m	0-3 GeV	72.25	0.4112	175.7	2239
	All	117.42	1.7628	66.6	1757
400 m	0-3 GeV	67.93	0.3553	191.2	2264
	All	112.43	1.6580	67.8	1735
500 m	0-3 GeV	59.79	0.2739	218.3	2270
	All	103.17	1.4981	68.9	1675
600 m	0-3 GeV	43.51	0.1656	262.7	2124
	All	83.92	1.2472	67.3	1493
700 m	0-3 GeV	11.84	0.0468	252.8	1087
	All	28.09	0.4684	60.0	815

(Bob Zwaska's calculation)



NC and CC Backgrounds

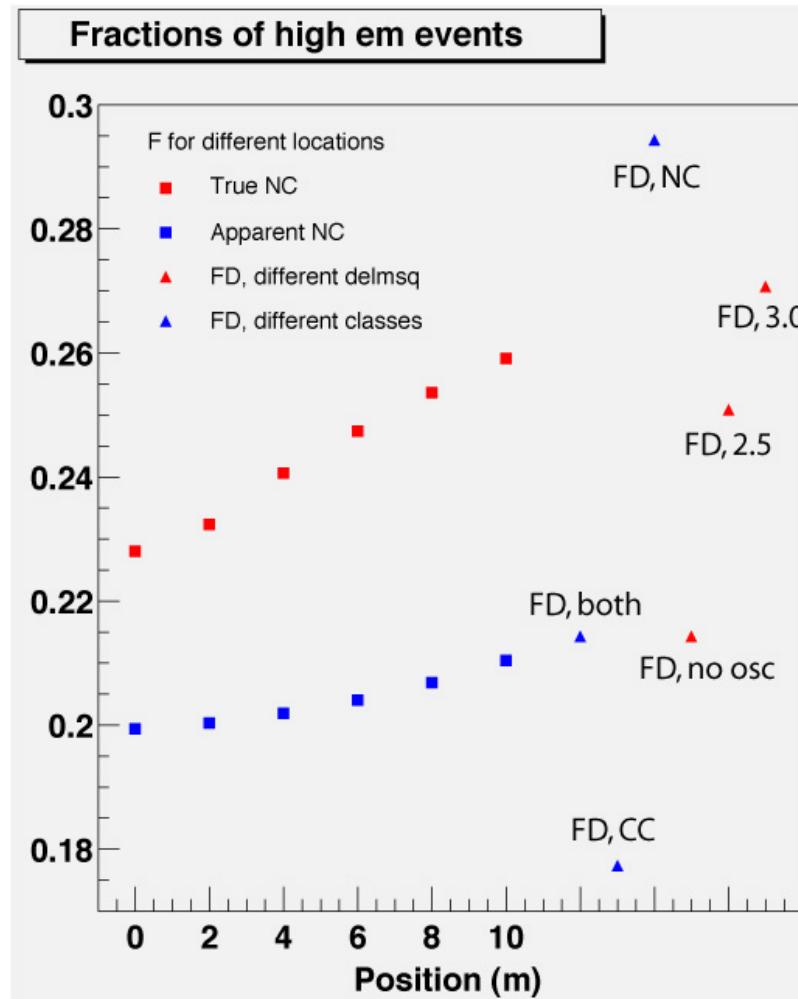
- CC and NC backgrounds extrapolate very differently from ND to FD
- Does this mean that we need to know well (and hence probably measure) their relative contributions?
- In principle this could be done with two ND's located at different transverse distances since CC/NC ratio of events with visible energy $\sim 2\text{GeV}$ changes with transverse distance
- One could also extrapolate potential background from CC events as a function of P_μ to $P_\mu < 0.5 \text{ GeV}$



Para Conjecture

- The number of background events from NC and ν_μ CC channels with $P_\mu < 0.5$ GeV is proportional to the number of those events with a high fraction (~50%) of the visible energy in an em component
- If true then the ratio of the numbers of those high em-fraction events with visible energy ~2GeV observed in the ND and FD will give the extrapolation factor for the background from those sources
- Is the constant of proportionality the same for NC and CC events?
- This procedure requires that you can subtract from both samples the number of beam ν_e events
- Ratio of these high-em events to all “apparent NC” events does not change very much as a function of detector position

Dependence on Location



Acceptance criteria

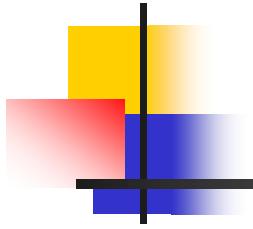
For CC, $p_\mu < 0.5 \text{ GeV}$

$1.5 < E_{\text{vis}} < 2.5 \text{ GeV}$

$E_{\text{em}}/E_{\text{vis}} > 0.5$

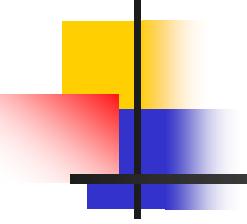
Para Calculation

Comment re Near Detector(s)



(what are minimum requirements)

- Detector with magnetic field, preferably on axis to measure spectrum - MINOS ND
- Detector using Far Detector technology to measure backgrounds - optimum position needs to be studied. Ideally wide enough to measure angular dependence
- Fine grained detector to measure exclusive channels and their internal distributions; ideally the front part of the detector above



Final Comments

- The quality of the measurement is crucially dependent on our ability to understand level of background
- The problem is made more difficult by the fact that there are several sources of background
- The background estimate will be easier if contributions from NC and CC channels are minimized
- There are a number of different ways to measure and/or calculate these backgrounds
- We need to develop a strategy that is convincing to outside reviewers
- It is important that the strategy adopted contain a number of self-consistency checks